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The *Usefulness* of
MATHEMATICAL LEARNING.

ESSAYS

1789

ON

The Usefulness of

Mathematical Learning

AND

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The *Usefulness* of
MATHEMATICAL LEARNING,

IN

A Letter from a *Gentleman* in
the CITY to his *Friend* in
OXFORD.



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AN
ESSAY
ON

The *Usefulness* of
MATHEMATICAL LEARNING, &c.

SIR,

I AM glad to hear from you, that the study of the *Mathematicks* is Promoted and Encouraged among the *Youth* of your *University*. The great influence, which these *Sciences* have on Philosophy and all useful Learning, as well as the Concerns of the Publick, may sufficiently recommend them to your choice and consideration: and the particular advantages, which You of that place enjoy, give Us just reason to expect from You a suitable improvement in them. I have here sent you some short reflections upon the *Usefulness* of *Mathematical Learning*, which may serve as an argument to incite you to a closer and more vigorous pursuit of it.

In all Ages and Countries, where Learning hath prevailed, the *Mathematical Sciences* have been looked upon as the most considerable branch of it. The very name *Μαθηματικά* implies no less; by which they were called either for their excellency, or because of all the *Sciences* they were first taught, or because they were judg'd to comprehend *πάντα τὰ Μαθηματικά*. And amongst those, that are commonly reckoned to be the seven Liberal Arts, four are Mathematical, to wit, *Arithmetick*, *Musick*, *Geometry*, and *Astronomy*.

But notwithstanding their Excellency and Reputation, they have not been taught nor study'd so universally, as some of the rest; which I take to have proceeded from the following causes: The aversion of the greatest part of Mankind to serious attention and close arguing; Their not comprehending sufficiently the necessity or great usefulness of these in other parts of Learning; An Opinion that this study requires a particular Genius and turn of Head, which few are so happy as to be Born with; And the want of Publick Encouragement, and able Masters. For these, and perhaps some other reasons, this study hath been generally

generally neglected, and regarded only by some few persons, whose happy Genius and Curiosity have prompted them to it, or who have been forced upon it by its immediate subserviency to some particular Art or Office.

Therefore I think I cannot do better service to Learning, Youth, and the Nation in general, than by shewing, *That the Mathematicks of all parts of humane knowledge, for the improvement of the Mind, for their subserviency to other Arts, and their usefulness to the Common-wealth, deserve most to be encouraged.* I know a discourse of this nature will be offensive to some, who, while they are ignorant of Mathematicks, yet think themselves Masters of all valuable Learning: but their displeasure must not deterr me from delivering an useful truth.

The advantages, which accrue to the Mind by *Mathematical* studies, consist chiefly in these things: 1st. In accustoming it to *attention*. 2^{dly}. In giving it a habit of *close and demonstrative reasoning*. 3^{dly}. In freeing it from *prejudice, credulity, and superstition*.

First, the Mathematicks make the Mind attentive to the objects, which it

considers. This they do by entertaining it with a great variety of truths, which are delightful and evident, but not obvious. Truth is the same thing to the understanding, as Musick to the ear, and Beauty to the eye. The pursuit of it does really as much gratifie a natural faculty implanted in us by our wise Creator, as the pleasing of our Senses: only in the former case, as the Object and Faculty are more Spiritual, the delight is the more pure, free from the regret, turpitude, lassitude, and intemperance, that commonly attend sensual pleasures. The most part of other *Sciences* consisting only of probable reasonings, the Mind has not where to fix; and wanting sufficient principles to pursue its searches upon, gives them over as impossible. Again, as in *Mathematical investigations* truth may be found, so it is not always obvious: This spurs the Mind, and makes it diligent and attentive. In *Geometria* says Quintilian, (lib. I. cap. 10.) *partem fatentur esse utilem teneris aetatibus: agitari namque animos, atque acui ingenia, & celeritatem percipiendi venire inde concedunt.* And Plato (in *Repub. lib. VII.*) observes, that the Youth, who are

Of Mathematical Learning.

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are furnished with *Mathematical* knowledge, are prompt and quick at all other *Sciences*, *ἐν πᾶσι τὰ Μαθηματικὰ ὅλως φαίνονται*. Therefore he calls it *κατὰ πρῶτον ὁδόν*. And indeed Youth is generally so much more delighted with *Mathematical* studies, than with the unpleasant tasks, that are some times imposed upon them, that I have known some reclaimed by them from idleness and neglect of learning, and acquire in time a habit of thinking, diligence, and attention; qualities, which we ought to study by all means to beget in their desultory and roving Minds.

The second advantage, which the Mind reaps from *Mathematical* knowledge, is a habit of *clear, demonstrative, and methodical Reasoning*. We are contriv'd by Nature to learn by Imitation more than by Precept: And I believe in that respect Reasoning is much like other inferior Arts (as *Dancing, Singing, &c.*) acquired by practice. By accustoming our selves to Reason closely about quantity, we acquire a habit of doing so in other things. It is surprizing to see, what superficial, inconsequential Reasonings, satisfy the most part of Mankind.

kind. A piece of wit, a jest, a simile, or a quotation of an Author, passes for a mighty Argument: with such things as these are the most part of Authors stuffed: and from these weighty premises they infer their conclusions. This weakness and effeminacy of Mankind in being perswaded where they are delighted, have made them the sport of Orators, Poets, and Men of wit. Those *lumina Orationis* are indeed very good diversion for the Fancy, but are not the proper business of the Understanding; and where a Man pretends to write on abstract subjects in a Scientifical method, he ought not to debauch in them. Logical precepts are more useful, nay, they are absolutely necessary for a rule of formal arguing in publick disputations, and confounding an obstinate and perverse adversary, and exposing him to the audience, or readers. But in the search of truth, an imitation of the method of the *Geometers* will carry a Man further than all the *Dialectical* rules. Their *Analysis* is the proper model we ought to form our selves upon, and imitate in the regular disposition and gradual progress of our enquiries; and even he,

he, who is ignorant of the nature of *Mathematical Analysis*, uses a method somewhat Analogous to it. The *Composition* of the *Geometers*, or their method of demonstrating truths already found out, viz. by *Definitions of words agreed upon, by Self-evident truths, and Propositions that have been already demonstrated*, is practicable in other subjects, tho' not to the same perfection, the natural want of evidence in the things themselves not allowing it; but it is imitable to a considerable degree. I dare appeal to some writings of our own Age and Nation, the Authors of which have been Mathematically inclined. I shall add no more on this head, but that one, who is accustomed to the methodical Systems of truths, which the *Geometers* have reared up in the several branches of those *Sciences*, which they have cultivated, will hardly bear with the confusion and disorder of other *Sciences*, but endeavour as far as he can to reform them.

Thirdly, *Mathematical* knowledge adds a manly vigour to the Mind, frees it from *prejudice, credulity, and superstition*. This it does two ways, 1st. by accustoming us to examine, and not to take things upon

upon trust. *zally*. By giving us a clear and extensive knowledge of the System of the World; which, as it creates in us the most profound reverence of the Almighty and wise Creator; so it frees us from the mean and narrow thoughts, which ignorance and superstition are apt to beget. How great an enemy *Mathematicks* are to superstition, appears from this, That in those Countries, where *Rogmissb Priests* exercise their barbarous Tyranny over the minds of Men, *Astronomers*, who are fully perswaded of the motion of the Earth, dare not speak out: But tho' the *Inquisition* may extort a Recantation, the Pope and a general Council too will not find themselves able to perswade to the contrary Opinion. Perhaps, this may have given occasion to a calumnious suggestion, as if *Mathematicks* were an enemy to Religion, which is a scandal thrown both on the one and the other; for truth can never be an enemy to true Religion, which appears always to the best advantage, when it is most examined.

— *Si propius stes,*

Te capiet magis. —

On the contrary, the *Mathematicks* are
friends

friends to Religion; inasmuch as they charm the passions, restrain the impetuosity of imagination, and purge the Mind from error and prejudice. Vice is error, confusion and false Reasoning; and all truth is more or less opposite to it. Besides, *Mathematical* studies may serve for a pleasant entertainment for those hours, which young Men are apt to throw away upon their Vices; the delightfulness of them being such, as to make solitude not only easy, but desirable.

What I have said may serve to recommend *Mathematicks* for acquiring a vigorous Constitution of Mind; for which purpose they are as useful, as exercise is for procuring Health and Strength to the Body. I proceed now to shew their vast extent and Usefulness in other parts of knowledge. And here it might suffice to tell you, that *Mathematicks* is the *Science* of quantity, or the *Art* of Reasoning about things that are capable of *more* and *less*, and that the most part of the objects of our knowledge are such: as matter, space, number, time, motion, gravity, &c. We have but imperfect ideas of things without quantity, and as imperfect a one of quantity it self without the

the help of *Mathematicks*. All the visible works of God Almighty are made in *number, weight, and measure*; therefore to consider them, we ought to understand *Arithmetick, Geometry, and Staticks*: and the greater advances we make in those Arts, the more capable we are of considering such things, as are the ordinary objects of our Conceptions. But this will farther appear from particulars.

And first, if we consider, to what perfection we now know the Courses, Periods, Order, Distances, and Proportions of the several great Bodies of the Universe, at least such as fall within our view; we shall have cause to admire the Sagacity and Industry of the *Mathematicians*, and the power of *Numbers* and *Geometry* well apply'd. Let us cast our Eyes backward, and consider *Astronomy* in its Infancy: or rather let us suppose it still to begin; for instance, a Colony of Rude Country people, transplanted into an Island remote from the commerce of all Mankind, without so much as the knowledge of the Kalendar, and the Periods of the Seasons, without Instruments to make Observations, or any the least notion of Observations or Instruments. When is it,
we

we could expect any of their posterity should arrive at the Art of predicting an Eclipse? Not only so, but the Art of reckoning all Eclipses that are past or to come, for any number of Years? When is it, we could suppose, that one of those Islanders transported to any other place of the Earth, should be able by the inspection of the Heavens to find how much he were South or North, East or West of his own Island, and to conduct his Ship back thither? For my part, tho' I know this may be, and is daily done, by what is known in *Astronomy*; yet when I consider the vast Industry, Sagacity, multitude of Observations, and other extrin-sick things necessary for such a sublime piece of knowledge, I should be apt to pronounce it impossible, and never to be hoped for. Now we are let so much into the knowledge of the Machine of the Universe, and motion of its parts by the Rules of this *Science*, perhaps the invention may seem easy. But when we reflect, what Penetration and Contrivance were necessary to lay the foundations of so great and extensive an Art, we cannot but admire its first Inventors: as *Thales Milesius*, who, as *Diogenes Laertius* and
Pliny

Pliny say, first predicted Eclipses; and his Scholar *Anaximander Milesius*, who found out the Globous Figure of the Earth, the Equinoctial Points, the Obliquity of the Ecliptick, the principles of Gnomonicks, and made the first Sphere or Image of the Heavens; and *Pythagoras*, to whom we owe the discovery of the true System of the World, and order of the Planets. Tho' it may be, they were assisted by the *Egyptians* and *Chaldeans*. But whoever they were, that first made these bold steps in this Noble Art, they deserve the praise and admiration of all future Ages.

*Felices anima, quibus hæc cognoscere primis,
Inque domos superas scandere cura fuit.
Credibile est illos pariter vitisq; jocisq;
Altius humanis exseruisse caput.
Non Venus & vinum sublimia pectora fregit,
Officiumque fori, militiaque labor.
Non levis ambitio, perfusaque gloria fuco,
Magnarumque fames sollicitavit opum.
Admovere oculis distantia sidera nostris,
Ætheraque ingenio supposuere suo.*

Ovid. in 1^o. Fast.

But tho' the industry of former Ages had discovered the Periods of the great Bodies

Bodies of the Universe, and the true System and Order of them, and their Orbits pretty near; yet was there one thing still reserved for the glory of this Age, and the honour of the *English Nation*, The grand secret of the whole Machine; which, now it is discovered, proves to be (like the other contrivances of Infinite Wisdom) simple and natural, depending upon the most known and most common property of matter, viz. *gravity*. From this the incomparable M^r. *Newton* has demonstrated the Theories of all the Bodies of the Solar System, of all the primary Planets and their secondaries, and among others, the Moon, which seem'd most averse to numbers: And not only of the Planets, the slowest of which compleats its Period in less than half the Age of a Man, but likewise of the Comets, some of which its probable spend more than 2000. years in one Revolution about the Sun; for whose Theory he has laid such a foundation, that after Ages assisted with more Observations, may be able to Calculate their returns. In a word, the precession of the *Æquinoctial Points*, the Tydes, the unequal Vibration of *Pendulous Bodies* in different Latitudes,

tudes, &c. are no more a question to those, that have *Geometry* enough to understand, what he has delivered on those Subjects: A perfection in *Philosophy*, that the boldest thinker durst hardly have hoped for; and, unless Mankind turn barbarous, will continue the Reputation of this Nation, as long as the Fabrick of Nature shall endure. After this, what is it, we may not expect from *Geometry* join'd to *Observations* and *Experiments*?

The next considerable object of Natural knowledge, I take to be *Light*. How unsuccessful enquiries are about this Glorious Body without the help of *Geometry*, may appear from the empty and frivolous discourses and disputations of a sort of Men, that call themselves *Philosophers*; whom nothing will serve forsooth, but the knowledge of the very Nature, and intimate Causes of every thing: while on the other hand, the *Geometers* not troubling themselves with those fruitless enquiries about the Nature of *Light*, have discovered two remarkable properties of it, in the reflection and refraction of its beams: and from those, and their streightness in other cases, have invented the noble Arts

Arts of *Opticks*, *Catoptricks*, and *Dioptricks*; teaching us to manage this subtile Body for the improvement of our knowledge, and useful purposes of Life. They have likewise demonstrated the causes of several Coelestial appearances, that arise from the inflection of its Beams, both in the Heavenly Bodies themselves and other Phœnomena, as *Parhelia*, the *Iris*, &c. and by a late Experiment they have discovered the celerity of its motion. And we shall know yet more surprizing properties of *Light*, when Mr. *Newton* shall be pleas'd to gratifie the World with his *Book of Light and Colours*.

The *Fluids* which involve our Earth, viz. *Air* and *Water*, are the next great and conspicuous Bodies, that Nature presents to our view: And I think we know little of either, but what is owing to *Mechanicks* and *Geometry*. The two chiefest properties of *Air*, its Gravity and Elastick force, have been discovered by Mechanical Experiments. From thence the decrease of the Air's density according to the increase of the distance of the Earth has been demonstrated by *Geometers*, and confirmed by Experiments of the subsidence of the *Mercury* in the

Toricellian Experiment. From this likewise, by assistance of *Geometry*, they have determined the height of the Atmosphere, as far as it has any sensible density; which agrees exactly with another Observation of the duration of the Twilight. *Air* and *Water* make up the object of the *Hydrostaticks*, tho' denominated only from the latter, of which the principles were long since settled and demonstrated by *Archimedes*, in his Book *τῶν ὀξεύων*, where are demonstrated the causes of several surprizing Phenomena of Nature, depending only on the *Equilibrium* of *Fluids*, the relative Gravities of these *Fluids*, and of Solids swimming or sinking therein. Here also the Mathematicians consider the different Pressures, Resistances, and Celerities of Solids moved in Fluids: from whence they explain a great many appearances of Nature, unintelligible to those who are ignorant of *Geometry*.

Next, if we descend to the *Animal Kingdom*, there we may see the brightest strokes of Divine Mechanicks. And whether we consider first the *Animal Oeconomy* in general, either in the internal motion and circulation of the Juices forced through

through the several Canals by the motion of the Heart, or their external motions, and the Instruments wherewith these are performed, we must reduce them to Mechanical Rules, and confess the necessity of the knowledge of Mechanicks to understand them, or explain them to others. *Borelli* in his excellent Treatise *de motu Animalium*, *Steno* in his admirable *Myologiae Specimen*, and other Mathematical Men on the one hand, and the nonsensical, unintelligible stuff that the common Writers on these Subjects have filled their Books with on the other, are sufficient instances to shew, how necessary *Geometry* is in such speculations. The only Organ of an Animal Body, whose structure and manner of operation is fully understood, has been the only one, which the *Geometers* have taken to their share to consider. It's incredible, how silly the greatest and ablest Physicians talked of the parts of the Eye and their use, and of the *modus visionis*, before *Kepler* by his *Geometry* found it out, and put it past dispute, tho' they apply'd themselves particularly to this, and valued themselves on it: and *Galen* pretended a particular Divine Commission

to treat of it. Nay, notwithstanding the full discovery of it, some go on in copying their Predecessors, and talk as *Ungeometrically* as ever. It's true, we cannot reason so clearly of the internal motions of an Animal Body, as of the external, wanting sufficient *data* and decisive Experiments: But what relates to the latter (as the Articulation, Structure, Insertion, and *Vires* of the Muscles) is as subject to strict Mathematical disquisition, as any thing whatsoever; and even in the Theory of Diseases and their Cures, those, who talk Mechanically, talk most intelligibly. Which may be the reason for the Opinion of the ancient Physicians, that Mathematicks are necessary for the study of Medicine it self, for which I could bring long quotations out of their works. Among the Letters that are ascrib'd to *Hippocrates*, there is one to his Son *Thessalus*, recommending to him the study of *Arithmetick* and *Geometry*, as necessary to Medicine. *Galen* in his Book intituled *ὅτι ἀριστος ἰατρός καὶ φιλόσοφος*, begins, Οἷόν τι πεπόνθῃσιν οἱ πολλοὶ τῶν ἀθλητῶν, Ἰππυμέεντες μὲν ὀλυμπιονίκαι γινέσθαι, μηδὲν ἢ πράττειν, ὡς τότε τυχεῖν, Ἰππηδευόντες, ποιῶντι ἢ πῶς πολλοῖς τῶν ἰατρῶν συμβέβηκεν ἐπαγνῶσι
μὲν

μὲν γὰρ Ἰπποκράτει καὶ πρῶτον ἀπάντων ἡγέοντι,
 ᾗ δέδοται ὅτι αὐτὸς ἐν ὁμοίοις ἐκείνῳ πάντι μᾶλλον
 ἢ τῷ πρῶτῳ. οἱ μὲν γὰρ ἔμικρὰν μοῖραν εἰς ἰα-
 τρείῳ Φησὶ συμβάλλεσθαι τὴν ἀστρονομίαν, καὶ δη-
 λανόν, τὴν ταύτης ἡγεμονίαν ἐξ ἀνάγκης Γεωμε-
 τρίαν. οἱ δὲ ἔμνον αὐτοὶ μετέχοντες τῶν ἑδ-
 τερον, ἀλλὰ καὶ πῶς μετῴσι μέμφομενται. If one
 of the reasons of the Ancients for this
 be now somewhat unfashionable, to wit,
 because they thought a Physician should
 be able to know the situation and aspects
 of the Stars, which they believed had in-
 fluence upon Men and their Diseases, (and
 positively to deny it, and say, that they
 have none at all, is the effect of want of
 Observation) we have a much better and
 undoubted one in its room; viz. That
 Mathematicks are found to be the best
 Instrument of promoting natural know-
 ledge. 2dly. If we consider, not only
 the Animal Oeconomy in general, but
 likewise the wonderful structure of the
 different sorts of Animals, according to
 the different purposes for which they
 were design'd, the various Elements they
 inhabit, the several ways of procuring
 their nourishment, and propagating their
 kind, the different enemies they have,
 and accidents they are subject to, here is

still a greater need of *Geometry*. It is pity, that the qualities of an expert *Anatomist* and skillful *Geometer* have seldom met in the same person. When such a one shall appear, there is a whole *Terra incognita* of delightful knowledge to employ his time, and reward his industry.

As for the other two Kingdoms; *Borelli* and other *Mathematical Men*, seem to have talked very clearly of *Vegetation*: and *Steno* another Mathematician, in his excellent Treatise *de Solido intra Solidum naturaliter contento*, has apply'd this part of learning very handsomely to *Fossils* and some other parts of Natural History. I shall add only one thing more, That if we consider motion it self, the great Instrument of the Actions of Bodies upon one another, the Theory of it is entirely owing to the *Geometers*; who have demonstrated its Laws both in hard and elastick Bodies; shew'd how to measure it's quantity, how to compound and resolve the several forces, by which Bodies are agitated, and to determine the *Lines*, which those compound forces make them describe: of such forces gravity, being the most constant and uniform, affords a great variety of useful knowledge,

ledge, in considering several motions that happen upon the Earth; *viz.* As to the free descent of heavy Bodies; The curve of projectiles; The descent and weight of heavy Bodies when they lye on inclined plains; The Theory of the motion of Pendulous Bodies, &c.

From what I have said, I shall draw but one Corollary, That a natural Philosopher without Mathematicks is a very odd sort of a person, that reasons about things that have *Bulk, Figure, Motion, Number, Weight, &c.* without *Arithmetick, Geometry, Mechanicks, Staticks, &c.* I must needs say, I have the last contempt for those Gentlemen, that pretend to explain how the Earth was framed, and yet can hardly measure an Acre of Ground upon the surface of it: And as the Philosopher speaks, *Qui repente pedibus illotis ad Philosophos divertunt, non hoc est satis, quod sint omnino ἀθεωρητοι, ἀμυεστοι, ἀγνοήμεστοι. sed legem etiam dant, quā Philosophari discant.*

The usefulness of *Mathematicks* in several other Arts and Sciences is fully as plain. They were looked upon by the ancient Philosophers as the key to all knowledge. Therefore *Plato* wrote upon

his School, οὐδεὶς ἀγεωμέτρητος εἰσέλτω. *Let none unskilled in Geometry enter*; and *Xenocrates* told one ignorant in *Mathematicks*, who desired to be his Scholar, that he was fitter to Card Wooll, λαβὼς γὰρ ἔν ἔχεις φιλοσοφίας, *you want the bundle of Philosophy*, viz. *Geometry*. There is no understanding the works of the ancient Philosophers without it. *Theo Smyrnaeus* has wrote a Book entituled, *An explanation of those things in Mathematicks, that are necessary for the reading of Plato*: *Aristotle* illustrates his precepts and other thoughts by Mathematical examples, and that not only in *Logick*, &c. but even in *Ethicks*, where he makes use of Geometrical and Arithmetical proportion, to explain commutative and distributive justice.

Every body knows, that *Chronology* and *Geography* are indispensable preparations for *History*: a relation of matter of fact being a very lifeless insipid thing without the circumstances of time and place. Nor is it sufficient for one, that would understand things thoroughly, that he knows the *Topography*, that is, the name of the Country, where such a place lies, with those of the near adjacent places,

places, and how these lie in respect of one another; but it will become him likewise to understand the Scientific principles of the Art: that is, to have a true Idea of a place, we ought to know the relation it has to any other place, as to the distance and bearing, its Climate, Heat, Cold, length of days, &c. which things do much enliven the Readers notion of the very action it self. Just so, it is necessary to know the Technical or Doctrinal part of Chronology, if a Man would be thoroughly skill'd in History, it being impossible without it, to unravel the confusion of Historians. I remember Mr. *Hally* has determin'd the day and hour of *Julius Caesar's* Landing in *Britain*, from the circumstances of his relation. And every body knows, how great use our incomparable Historian Mr. *Dodwell* has made of the Calculated times of Eclipses, for settling the times of great Events, which before were as to this essential circumstance almost fabulous. Both *Chronology* and *Geography*, and also the knowledge of the Sun's and Moon's motions, so far as they relate to the constitution of the Kalendar and Year, are necessary to a Divine, and how sadly
some

some otherwise Eminent have blunder'd, when they meddled with things that relate to these, and border on them, is too apparent.

No body, I think, will question the interest, that Mathematicks have in *Painting*, *Musick*, and *Architecture*, which are all founded on numbers. Perspective and the Rules of Light and Shadows are owing to *Geometry* and *Opticks*: And I think those two comprehend pretty near the whole Art of *Painting*, except *decorum* and *ordinance*; which are only a due observance of the History and Circumstances of the subject, you represent. For by Perspective, may be understood the Art of designing the outlines of your solid, whether that be a Building, Landscape, or Animal: and the draught of a Man is really as much the Perspective of a Man, as the draught of a Building is of a Building; tho' for particular reasons, as because it consists of more crooked lines, &c. it is hard to reduce the Perspective of the former, to the ordinary established Rules.

If *Mathematicks* had not reduced *Musick* to a regular System, by contriving its *Scales*, it had been no Art, but Enthusiastick

astick Rapture, left to the roving fancy of every Practitioner. This appears by the extraordinary pains, which the Ancients have taken to fit numbers to three sorts of Musick, the *Diatonick*, *Chromatick*, and *Enharmonick*: which if we consider with their nicety in distinguishing their several *Modes*, we shall be apt to judge, they had something very fine in their *Musick*, at least for moving the passions with single Instruments and Voices. But *Musick* had been imperfect still, had not *Arithmetick* stepped in once more, and *Guido Aretinus* by inventing the temperament, making the Fifth false by a certain determined quantity, taught us to Tune our Organs, and intermix all the three kinds of the Ancients; to which we owe all the Regular and Noble Harmony of our modern *Musick*.

As for *Civil Architecture* (of Military I shall speak afterwards) there is hardly any part of *Mathematicks*, but is some way subservient to it. *Geometry* and *Arithmetick* for the due measure of the several parts of a Building, the Plans, Models, computation of Materials, time and charges: for ordering right its Arches and Vaults, that they may be
both

both firm and beautiful: *Mechanicks* for its strength and firmness, transporting and raising materials: and *Opticks* for the Symmetry and Beauty. And I would not have any assume the character of an *Architect* without a competent skill in all of these. You see that *Vitruvius* requires these and many more for making a compleat *Architect*. I must own, that should any one set up to practice in any of the fore-mentioned Arts, furnished only with his Mathematical Rules, he would produce but very clumsy pieces. He, that should pretend to draw by the Geometrical Rules of Perspective, or Compose *Musick* meerly by his skill in Harmonical numbers, would shew but aukward performances. In those Compos'd Subjects, besides the stiff Rules, there must be Fancy, Genius, and Habit. Yet nevertheless these Arts owe their being to *Mathematicks*, as laying the foundation of their Theory, and affording them Precepts, which being once invented, are securely rely'd upon by Practitioners. Thus many design, that know not a tittle of the reason of the Rules, they practice by; and many no better qualify'd in their way Compose *Musick*,

Musick, better perhaps than he could have done, that invented the *Scale*, and the *Numbers* upon which their Harmony is founded. As *Mathematicks* laid the foundation of these Arts, so they must improve them: and he, that would invent, must be skill'd in Numbers. Besides it is fit a Man should know the true grounds and reasons of what he studies: and he that does so, will certainly practice in his Art with greater judgement and variety, where the ordinary Rules fail him.

I proceed now to shew the more immediate usefulness of *Mathematicks* in *Civil Affairs*. To begin with *Arithmetick*, it were an endless task to relate its several uses in publick and private business. The regulation and quick dispatch of both, seem intirely owing to it. The Nations, that want it, are altogether barbarous, as some *Americans*, who can hardly reckon above twenty. And I believe it would go near to ruine the Trade of the Nation, were the easy practice of *Arithmetick* abolished: for example, were the Merchants and Tradefmen oblig'd to make use of no other than the *Roman* way of notation by Letters, instead of our present. And if we should feel the
want

want of our *Arithmetick* in the easiest Calculations, how much more in those, that are some thing harder; as Interest simple and compound, Annuities, &c. in which, it is incredible, how much the ordinary Rules and Tables influence the dispatch of business. *Arithmetick* is not only the great Instrument of private Commerce, but by it are (or ought to be) kept the publick Accounts of a Nation: I mean those, that regard the whole State of a Common-wealth, as to the number, fructification of its people, increase of Stock, improvement of Lands and Manufactures, Ballance of Trade, Publick Revenues, Coynage, Military power by Sea and Land, &c. Those, that would judge or reason truly about the State of any Nation, must go that way to work, subjecting all the fore-mentioned particulars to Calculation. This is the true *Political* knowledge. In this respect the affairs of a Common-wealth differ from those of a private Family, only in the greatness and multitude of particulars, that make up the accounts. *Machiavel* goes this way to work in his account of different Estates. What Sir *William Petty* and several others of our Country-

Country-men have wrote in *Political Arithmetick*, does abundantly shew the pleasure and usefulness of such Speculations. It is true, for want of good information, their Calculations some times proceed upon erroneous suppositions: but that is not the fault of the Art. But what is it, the Government could not perform in this way, who have the command of all publick Records?

Lastly, Numbers are applicable even to such things, as seem to be govern'd by no rule, I mean such as depend on *Chance*: The quantity of probability and proportion of it in any two proposed cases being subject to Calculation as much as any thing else. Upon this depend the principles of Game. We find Sharpers know enough of this, to cheat some men that would take it very ill to be thought Bubbles: And one Gamester exceeds another, as he has a greater sagacity and readiness in Calculating his probability to win or lose in any proposed case. To understand the Theory of *Chance* thoroughly, requires a great knowledge of Numbers, and a pretty competent one of *Algebra*. The several uses of *Geometry* are not much fewer than those of *Arithmetick*.
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It is necessary for ascertaining of property both in Plains and Solids, or in Surveying and Guaging. By it Land is sold by the measure as well as Cloth: Work-men are pay'd the due price of their labour, according to the superficial or solid measure of their work: and the quantity of liquors determined for a due regulation of their price and duty. All which do wonderfully conduce to the easy dispatch of business, and the preventing of frauds and controversies. I need not mention the Measuring distances, laying down of Plans and Maps of Countries, in which we have daily Experience of its usefulness. These are some familiar instances of things, to which *Geometry* is ordinarily apply'd: of its use in *Civil, Military, and Naval Architecture* we shall speak afterwards.

From *Astronomy* we have the regular disposition of our time, in a due succession of years, which are kept within their limits as to the return of the Seasons, and the motion of the Sun. This is no small advantage for the due repetition of the same work, Labour and Actions. For many of our Publick, Private, Military, and Country Affairs, Ap-
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 pointments,

pointments, &c. depending on the products of the Ground, and they on the Seasons; It is necessary, that the returns of them be adjusted pretty near to the motion of the Sun: and we should quickly find the inconveniency of a *vague* undetermined year, if we used that of the *Mahumetans*, whose beginning and every month wanders through all the days of ours or the Solar year, which shews the Seasons. Beside, the adjusting of the Moon's motion to the Sun's is required for the decent Observation and Celebration of the *Church-Feasts* and *Fasts* according to the Ancient Custom and Primitive Institution; and likewise for the knowing of the Ebbing and Flowing of the Tides, the Spring and Neap Tides, Currents, &c. So that what-ever some people may think of an *Almanack* where all these are set down, it is oftentimes the most useful paper that is published the same year with it: Nay, the Nation could better spare all the Voluminous Authors in the *Term-Catalogue*, than that single sheet. Besides, without a regular Chronology, there can be no certain History; which appears by the confusion amongst Historians before the right dis-

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position

position of the year, and at present among the *Turks*, who have the same confusion in their History as in their Kalendar. Therefore a matter of such importance might well deserve the care of the *Great Emperour*, to whom we owe our present Kalendar; who was himself a great proficient in *Astronomy*. *Pliny* has quoted several things from his Books of the *Rising* and *Setting* of the Stars, *Lib. XVIII. cap. 25, 26, &c.* and *Lucan* makes him say,

——— *Media inter praelia semper
Stellarum, Caelique plagis, superisque vacavi.*

The *Mechanicks* have produced so many useful Engines, subservient to convenience, that it would be a task too great to relate the several sorts of them: some of them keep Life it self from being a burden. If we consider such, as are invented for raising weights, and are employ'd in Building and other great works, in which no impediment is too great for them; or *Hydraulick* Engines for raising of Water, serving for great use and comfort to Mankind, where they have no other way to be supply'd readily with that necessary Element; or such as, by making

Wind

Wind and Water work for us, save Animal force and great charges, and perform those actions, which require a vast multitude of hands, and without which every Man's time would be too little to prepare his own Aliment and other necessities; or those Machines, that have been invented by Mankind for delight and curiosity, imitating the motions of Animals, or other works of Nature; we shall have reason to admire and extoll so excellent an Art. What shall we say of the several Instruments, which are contriv'd to measure time? We should quickly find the value of them, if we were reduced to the condition of those barbarous Nations, that want them. The *Pendulum-Clock* invented and compleated by that famous *Mathematician* Monsieur *Hugens* is an useful invention. Is there any thing more wonderful than several *Planetary Machines*, which have been invented to shew the motions of the Heavenly Bodies, and their places at any time? Of which the most Ingenious, according to the exactest Numbers and true System, was made by the same M. *Hugens*: to which we may very justly apply *Claudian's* noble Verses upon that of *Archimedes*.

*Jupiter in parvo cum cerneret Aethera vitro,
 Redit, & ad superos talia dicta dedit:
 Hucine mortales progressa potentia cura?
 Jam meus in fragili luditur orbe labor.
 Jura poli, rerumque fidem, legesque Deorum
 Ecce Syracusae transtulit arte senex.
 Inclusus variis famulatur spiritus astris,
 Et vicum certis motibus urget opus.
 Percurrit proprium mentitus signifer annum,
 Et simulata novo Cynthia mense redit.
 Jamq; suum volvens audax industria mundum
 Gaudet, & humana fidera mente regit.
 Quid falso insontem tonitru Salmoena miror?
 Emula naturae parva reperta manus.*

Here I ought to mention the *Sciathe-
 rical Instruments*, for want of which there
 was a time, when the *Grecians* themselves
 were forced to measure the Shadow, in
 order to know the Hour; and as *Pliny*
 (*cap. ult. lib. VII.*) tells us, the *Romans*
 made use of an erroneous Sun-dial for
 ninety nine years, till *Q. Marcius Philip-
 pus* their Cenfor set up a better; which
 no doubt at that time was thought a
 Jewel. And at last, that famous Pyramid
 was set up in the *Campus Martius*, to serve
 for a Gnomon to a Dial marked on the
 street.

street. To this sort of Engines ought to be referred *Sphaeras, Globes, Astrolabes, Projections of the Sphere, &c.* These are such useful and necessary things, that alone may recommend the Art, by which they are made. For by these we are able in our Closet to judge of the Celestial motions, and to visit the most distant places of the Earth, without the fatigue and danger of Voyages; to determine concerning their distance, Situation, Climate, Nature of the Seasons, length of their days, and their relation to the Celestial Bodies, as much as if we were Inhabitants. To all these I might add those Instruments, which the *Mathematicians* have invented to execute their own precepts, for making *Observations* either at Sea or Land, *Surveying, Gauging, &c.*

The *Catoptricks* and *Dioptricks* furnish us with variety of useful inventions, both for the promoting of knowledge, and the conveniencies of Life; whereby Sight, the great Instrument of our perception, is so much improv'd, that neither the distance, nor the minuteness of the Object are any more impediments to it. The *Telescope* is of so vast use, that, besides the delightful and useful purposes

it is apply'd to here below, as the descrying Ships, and Men, and Armies at a distance, we have by its means discovered new parts of the Creation, fresh instances of the surprizing Wisdom of the Adorable Creator. We have by it discovered the *Satellites* of *Jupiter*, the *Satellites* and *Ring* of *Saturn*, the Rotation of the Planets about their own Axes; besides other appearances, whereby the System of the World is made plain to *sense*, as it was before to *reason*. The *Telescope* has also improv'd the manner of *Astronomical Observations*, and made them much more accurate, than it was possible for them to be before. And these improvements in *Astronomy*, have brought along with them (as ever) correspondent improvements in *Geography*. From the Observation of *Jupiter's Satellites*, we have a ready way to determine the Longitude of places on the Earth. On the other hand, the *Microscope* has not been less useful in helping us to the sight of such Objects, as by their minuteness escape our naked eye. By it Men have pursued Nature into its most retir'd recesses; so that now it can hardly any more hide its greatest Mysteries from
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from us. How much have we learned by the help of the *Microscope* of the contrivance and structure of Animal and Vegetable Bodies, and the composition of Fluids and Solids? But if these *Sciences* had never gone further, than by their single *Specula* and *Lentes* to give those surprizing appearances of Objects and their Images, and to produce heat unimitable by our hottest Furnaces, and to furnish infallible, easy, cheap, and safe remedies for the decay of our Sight arising commonly from old Age, and for purblindness; they had merited the greatest esteem, and invited to the closest study: especially if we consider, that such as naturally are almost blind, and either know not their nearest acquaintance at the distance of a rooms breadth, or cannot read in order to pass their time pleasantly, are by Glasses adapted to the defect of their Eyes set on a level again with those that enjoy their Eye-sight best, and that without danger, pain, or charge.

Again, *Mathematicks* are highly serviceable to a Nation in *Military Affairs*. I believe this will be readily acknowledg'd by every body. The Affairs of War take in Number, Space, Force, Distance,
C 4 Time,

Time, &c. (things of *Mathematical* consideration) in all its parts, in *Tactics*, *Castrametation*, *Fortifying*, *Attacquiring*, and *Defending*. The Ancients had more occasion for *Mechanicks* in the Art of War than we have: Gun-powder readily producing a force far exceeding all the Engines, they had contriv'd for Battery. And this I reckon has lost us a good occasion of improving our *Mechanicks*: the cunning of Mankind never exerting it self so much, as in their Arts of destroying one another. But, as Gun-powder has made *Mechanicks* less serviceable to War; it has made *Geometry* more necessary: There being a force or resistance in the due measures and proportions of the Lines and Angles of a Fortification, which contribute much towards its strength. This Art of *Fortification* has been much study'd of late, but I dare not affirm, that it has attain'd its utmost perfection. And tho', where the ground is regular, it admits but of small variety, the measures being pretty well determined by *Geometry* and Experience, yet where the ground is made up of natural *Strengths* and *Weaknesses*, it affords some scope for thinking and contrivance.

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But there is another much harder piece of *Geometry*, which Gun-powder has given us occasion to improve, and that is the doctrine of Projectiles; whereon the Art of *Gunnery* is founded. Here the *Geometers* have invented a beautiful Theory, and Rules and Instruments, which have reduced the casting of Bombs to great exactness. As for *Tactics* and *Castrametation*, *Mathematicks* retain the same place in them as ever. And some tolerable skill in these ~~are~~ necessary for *Officers*, as well as for *Engineers*. An *Officer*, that understands Fortification, will *ceteris paribus* much better defend his post, as knowing, wherein its strength consists, or make use of his advantage to his Enemy's Ruine, than he that does not. He knows, when he leads never so small a party, what his advantages and disadvantages in Defending and Attacquiring are, how to make the best of his Ground &c. And hereby can do truely more service than another of as much Courage, who, for want of such knowledge, it may be, throws away himself and a number of brave Fellows under his Command: and it's well, if the mischief reaches no further. As for a competent skill

skill in *Numbers*, it is so necessary to *Officers*, that no Man can be safely trusted with a Company, that has it not. All the business is not to fire Musquets; the managing of Affairs, the dealing with Agents, &c. happen more frequently. And the higher the Command is, the more skill in all the aforesaid things is required. And I dare appeal to all the Nations in *Europe*, whether *ceteris paribus* Officers are not advanced in proportion to their skill in *Mathematical Learning*; except, that some times *Great Names* and *Quality* carry it; but still so, as that the Prince depends upon a Man of *Mathematical Learning*, that is put as director to the *Quality*, when that Learning is wanting in it.

Lastly, *Navigation* which is made up of *Astronomy* and *Geometry*, is so noble an Art, and to which Mankind owes so many advantages, that upon this single account those Excellent Sciences deserve most of all to be study'd, and merit the greatest encouragement from a Nation, that owes to it both its Riches and Security. And not only does the Common Art of *Navigation* depend on *Mathematicks*, but whatever improvements shall

shall be made in the *Architectura Navalis* or Building of Ships, whether they are design'd for Merchant-Ships, or Ships of War, whether swift running, or bearing a great sail, or lying near the wind be desired, these must all be the improvements of *Geometry*. *Ship-Carpenters* indeed are very industrious; but in these things they acknowledge their inability, confess that their best productions are the effects of chance, and implore the *Geometers* help. Nor will common *Geometry* do the business; it requires the most abstruse to determine the different sections of a Ship, according as it is design'd for any of the foresaid ends. A *French* Mathematician *P. Le Hoste* has lately endeavour'd some thing in this way: and tho' it is not free from errors, as requiring a fuller knowledge in *Geometry*; yet is the Author much to be commended for this, as having bravely design'd, and pav'd the way for other Mathematicians; and also for the former and bigger part of his Book, wherein he brings to a system the working of Ships, and the *Naval Tactics*, or the regular disposition of a Fleet in Attacking, Fighting and Retreating, according

ing to the different circumstances of Wind, Tides, &c.

The great objection, that is made against the necessity of *Mathematicks*, in the fore-mention'd great Affairs of *Navigation*, the Art *Military*, &c. is, that we see those Affairs are carry'd on and managed by such, as are not great Mathematicians; as Sea-men, Engineers, Surveyers, Gaugers, Clock-makers, Glass-grinders, &c. and that the Mathematicians are commonly Speculative, Retir'd, Studious Men, that are not for an active Life and business, but content themselves to sit in their Studies, and pore over a *Scheme* or a *Calculation*. To which there is this plain and easy answer: The Mathematicians have not only invented and order'd all the Arts above-mentioned, by which those grand Affairs are managed; but have laid down Precepts, contriv'd Instruments and Abridgements so plainly, that common Artificers are capable of practising by them, tho' they understand not a tittle of the grounds, on which the Precepts are built. And in this they have consulted the good and necessities of Mankind. Those Affairs demand so great a number of people

ple to manage them, that it is impossible to breed so many good or even tolerable Mathematicians. The only thing then to be done was to make their Precepts so plain, that they might be understood and practised by a multitude of Men. This will best appear by examples. Nothing is more ordinary than dispatch of business by common *Arithmetick*, by the *Tables of simple and compound Interest, Annuities &c.* Yet how few Men of business understand the reasons of common *Arithmetick*, or the contrivance of those Tables, now they are made; but securely rely on them as true. They were the good and the Thorough-Mathematicians, that made those Precepts so plain, and Calculated those Tables, that facilitate the practice so much. Nothing is more universally necessary, than the measuring of Plains and Solids: And it is impossible to breed so many good Mathematicians, as that there may be one, that understands all the *Geometry* requisite for Surveying, and measuring of *Prisms* and *Pyramids*, and their parts, and measuring *Frustums* of *Conoids* and *Spheroids*, in every Market-Town, where such work is necessary:
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the Mathematicians have therefore inscrib'd such Lines on their common Rulers, and Slipping Rulers, and adapted so plain Precepts to them, that every Country-Carpenter, and Gauger, can do the business accurately enough; tho' he knows no more of those Instruments, Tables, and Precepts he makes use of, than a Hobby-horse. So in *Navigation*, it is impossible to breed so many good Mathematicians, as would be necessary to sail the hundredth part of the Ships of the Nation. But the Mathematicians have laid down so plain and distinct Precepts, Calculated necessary Tables, and contriv'd convenient Instruments, so that a Sea-man, that knows not the truths, on which his Precepts and Tables depend, may practice safely by them. They *resolve* Triangles every day, that know not the reason of any one of their *Operations*. Sea-men in their Calculations make use of *artificial Numbers* or *Logarithmes*, that know nothing of their contrivance: and indeed all those great inventions of the most famous Mathematicians had been almost useless for those common and great Affairs, had not the practice of them been made easy to those
who

who cannot understand them. From hence it is plain, that it is to those *Speculative Retir'd Men*, we owe the Rules, the Instruments, the Precepts for using them, and the Tables which facilitate the dispatch of so many great Affairs, and supply Mankind with so many conveniencies of Life. They were the Men, that taught the World to apply *Arithmetick*, *Astronomy*, and *Geometry* to *Sailing*, without which the needle would be still useless. Just the same way in the other parts of *Mathematicks*, the Precepts that are practis'd by multitudes, without being understood, were contriv'd by some few great *Mathematicians*.

Since then it has been shewn, how much *Mathematicks* improve the Mind, how subservient they are to other Arts, and how immediately useful to the Commonwealth, there needs no other arguments or motives to a Government, to encourage them. This is the natural conclusion from these premises. *Plato* in his *Republick* (lib. VII.) takes care, That, whoever is to be Educated for Magistracy, or any considerable Post in the Commonwealth, may be instructed first in *Arithmetick*, then in *Geometry*, and thirdly in *Astronomy*.
And

And however necessary those Arts were in *Plato's* time, they are much more so now: The Arts of War and Trade requiring much more the assistance of those *Sciences* now, than they did then; as being brought to a greater height and perfection. And accordingly we see, these *Sciences* are the particular care of Princes, that design to raise the Force and Power of their Countries. It is well known, that this is none of the least Arts, whereby the *French King* has brought his subjects to make that Figure at Sea, which they at this time do; I mean, the care He takes for Educating those appointed for Sea-service in *Mathematical Learning*. For in the *Ordonnance Marine Title VIII*. 'He orders, that there be Professors to
'teach Navigation publickly in all the
'Sea-port Towns, who must know *de-*
'*signing*, and teach it to their Scholars,
'in order to lay down the appearances
'of Coasts, &c. They are to keep their
'Schools open, and read four times a
'week to the Sea-men, where they must
'have Charts, Globes, Spheres, Com-
'passes, Quadrants, Astrolabes, and all
'Books and Instruments necessary to
'teach their Art. The directors of Hos-
'pitals

‘pitals are oblig’d to send thither yearly
‘two or three of their boys to be taught,
‘and to furnish them with Books and
‘Instruments. Those Professors are
‘oblig’d to examine the Journals depo-
‘sited in the Office of Admiralty, in the
‘place of their establishment; to correct
‘the errors in presence of the Sea-men,
‘and to restore them within a month, &c.
King *Charles* the second, who well un-
derstood the importance of Establish-
ments of this nature, founded one such
School in *Christ’s Hospital London*; which,
I believe, is inferiour to none of the
French: but ’tis to be wished there were
many more such. His present *Majesty*,
during the time of the late War, esta-
blished a *Mathematical Lecture* to breed
up Engineers and Officers, as knowing
very well the importance thereof. And
this continued some time after the *Peace*.
And it is worthy the consideration of the
Wisdom of the Nation, whether the restor-
ing and continuing this, even in *Peace*, be
not expedient for the breeding of En-
gineers, who are so useful and valuable,
and so difficult to be had in time of War,
and so little dangerous in times of
Peace.

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Besides

Besides the crowd of *Merchants, Seamen, Surveyors, Engineers, Ship-carpenters, Artisans, &c.* that are to be instructed in the practice of such parts of *Mathematicks*, as are necessary to their own business respectively, a competent number of *able Mathematicians* ought to be entertained, in order to apply themselves to the practice; not only to instruct the former sort, but likewise to remove those obstacles, which such, as do not think beyond their common Rules, cannot overcome. And no doubt it is no small impediment to the advancement of Arts, that *Speculative Men* and good *Mathematicians* are unacquainted with their particular defects, and the several circumstances in them, that render things *practicable* or *impracticable*. But if there were publick encouragement, we should have skilful Mathematicians employed in those Arts, who would certainly find out and remedy the imperfections of them. The present Lords Commissioners of the Admiralty knowing, that there are still two great *Desiderata* in Navigation, to wit, *The Theory of the variation of the magnetical Needle*, and a method of finding out the Longitude of any place,

that

that may be practicable at Sea by Seamen, and being sensible, of what importance it would be to find out either of them, have imployed a very fit person, the ingenious Mr. *Hally*, who has joyn'd an entire acquaintance in the practice, to a full and thorough knowledge of the more abstruse parts of *Mathematicks*. And now that he is returned, it is not doubted, but he will satisfy those, that sent him, and in due time the World too with his discoveries in both those particulars, and in many other, that he has had occasion to make. And where a long series of Observations and Experiments is necessary, he has no doubt laid such a foundation, as that After-Observers may gradually perfect them. If it were not for more than the correcting the situation of the Coasts, where he touched, and by them others, whose relation to the former is known, the Nation is more then triply pay'd; and those, who sent him, have by this Mission secured to themselves more true Honour and lasting Fame, than by Actions, that at first view appear more Magnificent.

The next thing, that is necessary for the improvement of *Mathematical Learning*, is, That Mathematicks be more generally study'd at our *Universities* than hitherto they have been. From those Seminaries the State justly expects and demands those, who are acquainted both with the *Speculation* and *Practice*. In those are all the encouragements to them imaginable, Leisure and Assistance. There are still at hand Books and Instruments, as also other Scholars that have made equal progress, and may be Comrades in study, and the direction of the Professors. There are also in perfection all the incitements to this study, and especially an acquaintance with the works of the Ancients, where this *Learning* is so much recommended: There other Faculties are study'd, to which it is subservient. There also are the Nobility and Gentry bred, who, in due time must be called to their share in the Government of the *Fleets, Army, Treasury*, and other Publick Employments, where *Mathematical Learning* is absolutely necessary, and without which, they, tho' of never so great Natural parts, must be at the mercy and discretion of their Servants and Deputies;

ties; who will first cheat them, and then laugh at them. And not only Publick Employments, but their Private Concerns demand Mathematical knowledge. If their Fortunes lie in Woods, Coal, Salt, Manufactures, &c. the necessity of this knowledge is open and known: and even in Land-Estates, no undertaking for improvement can be securely rely'd upon without it. It not only makes a Man of Quality and Estate his whole Life more illustrious, and more useful for all Affairs, (as *Hippocrates* says, ἱσ-
 τῆς ὁ μελέτωσι ὧ παῖ, Γεωμετρικῆς καὶ Ἀριθ-
 μητικῆς· ἡ γὰρ μόνον, αἶσα καὶ τὸν βίον εὐκλεία καὶ
 ὅτι πολλὰ χρήσιμον ἐς ἀνθρωπίνην μαίεσιν ὅστις
 λίσσει, ἀλλὰ καὶ τὴν ψυχὴν ὀξυτέρῳ καὶ τη-
 λαυγέστερῳ &c.) but in particular, it is the best Companion for a Country Life. Were this once become a fashionable study (and the *Mode* exercises its Em-
 pire over Learning as well as other things) it is hard to tell, how far it might influence the Morals of our Nobility and Gentry, in rendering them Se-
 rious, Diligent, Curious, taking them off from the more fruitless and airy exer-
 cises of the Rancy, which they are apt to run into.

The only Objection, I can think of, that is brought against these studies, is, that Mathematicks require a particular turn of Head, and a happy Genius that few people are Masters of, without which all the pains bestowed upon the study of them are in vain: They imagine that a *Man must be Born a Mathematician*. I answer, that this *Exception* is common to Mathematicks and other Arts. That there are persons, that have a particular capacity and fitness to one more than another, every body owns: And from experience I dare say, it is not in any higher degree true concerning Mathematicks than the others. A Man of good sense and application is the person, that is by nature fitted for them: especially if he begins betimes; And if his circumstances have been such, that this did not happen, by prudent direction the defect may be supply'd as much as in any Art whatsoever. The only advantage this Objection has, is, that it is on the side of softness and idleness, those powerful Allies.

There is nothing further remains, Sir, but that I give you my thoughts in general concerning the *Order and Method*

of

of studying *Mathematicks*; which I shall do very shortly, as knowing that you are already acquainted with the best methods, and others with you may have them easily from the best and ablest hands.

First then, I lay down for a principle, that no body at an *University* is to be taught the practice of any rule without the true and solid reason and demonstration of the same. Rules without demonstration must and ought to be taught to *Sea-men, Artisans, &c.* as I have already said; and Schools for such people are fit in Sea-ports and Trading-Towns; but it is far below the dignity of an *University*, which is design'd for solid and true Learning, to do this. It is from the *Universities*, that they must come, who are able to remedy the defects of the Arts: and therefore nothing must be taken on trust there. *Sea-men* and *Surveyors, &c.* remember their Rules, because they are perpetually practising them: But *Scholars*, who are not thus employ'd, if they know not the demonstration of them, presently forget them.

Secondly, no part of Mathematicks ought to be taught by *Compendiums*. This follows from the former. *Compendiums* are fit to give a general and superficial knowledge, not a thorough one. It's time, and not the bulk of Books, we ought to be sparing of: And I appeal to any person of Experience, whether solid knowledge is not acquir'd in shorter time by Books treating fully of their subjects, than by *Compendiums* and *Abridgements*.

From hence it follows, that the *Elements* of *Arithmetick* and *Geometry* are to be taught. *Euclid* in his thirteen Books of *Elements* gives us both: but our present way of Notation supersedes some of those of *Arithmetick*, as demonstrating the Rules from the Operations themselves. There remain then the first six Books for the *Geometry* of *Plains*, and the last three for *Stereometry*. The rest ought to be read in their own place for the perfection of *Arithmetick*. In teaching these, care ought to be taken to make use of such Examples, as suit with the condition of the Scholar. For instance, *Merchants Accounts* and *Affairs*
for

for Examples of the Operations of *Arithmetick*, to one that is afterwards to have a concern that way; whereas to a Man of the first Quality, examples from *the encrease and decrease of the people*, or from *Land or Sea-Force*, and from the *Tacticks* ought to be proposed. For it is certain, nothing makes one tyrd sooner, than the frivolous and trifling examples, that are commonly brought for the exercise of the Rules of *Arithmetick* and *Geometry*: tho' this is common to them with the other Arts, as *Grammar, Logick, &c.*

The manner of Writing of the Mathematicians of this and the former Age makes *Trigonometry*, with the manner of constructing its Tables, &c. almost *Elementary*; and the *practical Geometry* commonly so call'd, is very fit to come next, as an elegant application of the *Elements of Geometry* to Business, as *Surveying, Gauging, &c.*

After the Elements of *Sphericks*, which are perfectly well handled by *Theodosius*, a full insight into the principles of *Astronomy* will be necessary.

Mecha-

Mechanicks come next to be read, which are the Ground of a great part of Natural Learning; and afterwards *Opticks*, *Catoptricks* and *Dioptricks*.

But none of these except the Elements can be fully understood until one is pretty well skill'd in *Conick-sections*: And all these are made more easy by some tolerable skill in *Algebra*, and its application to *Geometry*.

These foundations being laid, any one may with great ease pursue the study of the *Mathematicks*, as his occasions require: either in its abstract parts, and the more *recondite Geometry*, and its application to Natural knowledge; or in *Mechanicks*, by prosecuting the *Statics*, *Hydrostaticks*, *Ballisticks*, &c; or in *Astronomy*, by its application to *Geography*, *Navigation*, *Gnomonicks*, *Astrolabes*, &c. But in most of these a particular order is not necessary. Any one may take that first, which he is most inclin'd to.

I shall not offer you any advice concerning the choice of Books, but refer you (if you want any) to the direction of those, who are Eminent among you
in

in this part of Learning. I ask your pardon for the omission of *Ceremony* in these papers, having followed rather the ordinary way of *Essay* than *Letter*. and wishing you good success in your studies, I am,

Sir,

Your Friend and Servant.

25. *Novemb.*

1700.

F I N I S.

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